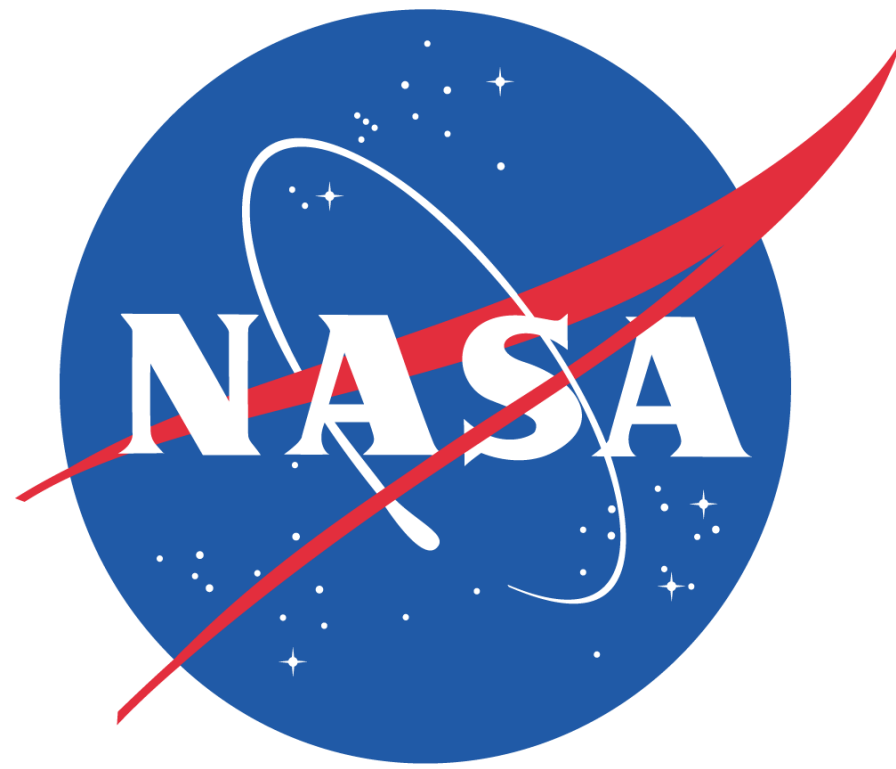
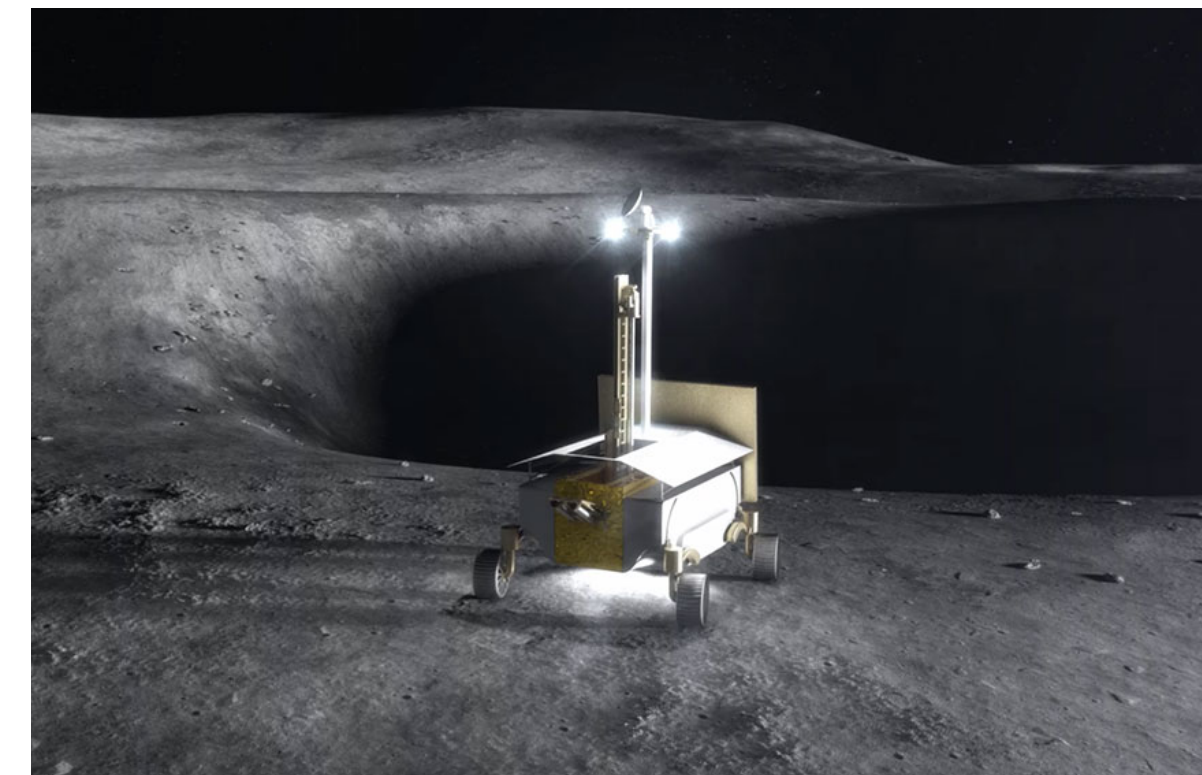


# CHALLENGES OF ROVER NAVIGATION AT THE LUNAR POLES



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## Introduction

Observations from Lunar Prospector, LCROSS, Lunar Reconnaissance Orbiter (LRO), and other missions have contributed evidence that water and other volatiles exist at the lunar poles in permanently shadowed regions. Combining a surface rover and a volatile prospecting and analysis payload would enable the detection and characterization of volatiles in terms of nature, abundance, and distribution. This knowledge could have impact on planetary science, in-situ resource utilization, and human exploration of space. While Lunar equatorial regions of the Moon have been explored by manned (Apollo) and robotic missions (Lunokhod, Cheng'e), no surface mission has reached the lunar poles.

## Navigation Challenges

Challenges to navigating a surface rover at the poles include:

Gaps in knowledge of the terrain and surface conditions:

- Digital elevation model resolution
- Regolith properties
- Albedo characterization,
- Unknown rock distribution,
- Unknown terrain within PSR except where LOLA is available.

Gaps in knowledge of illumination conditions due to:

- low sun angles
- long shadows cast by uncertainties in terrain relief
- uncertainties in Lunar polar surface reflectance model

Communication with Earth

- high latency (one way light time plus network)
- low bandwidth

Solar power concept

- low mass navigation sensor, wheels
- reduced on-board power available
- direct sun light orientation

Temperature conditions

- sensor selections
- direct light/shadows temperature management

Limited on board computer processor

- radiation hardened
- low power

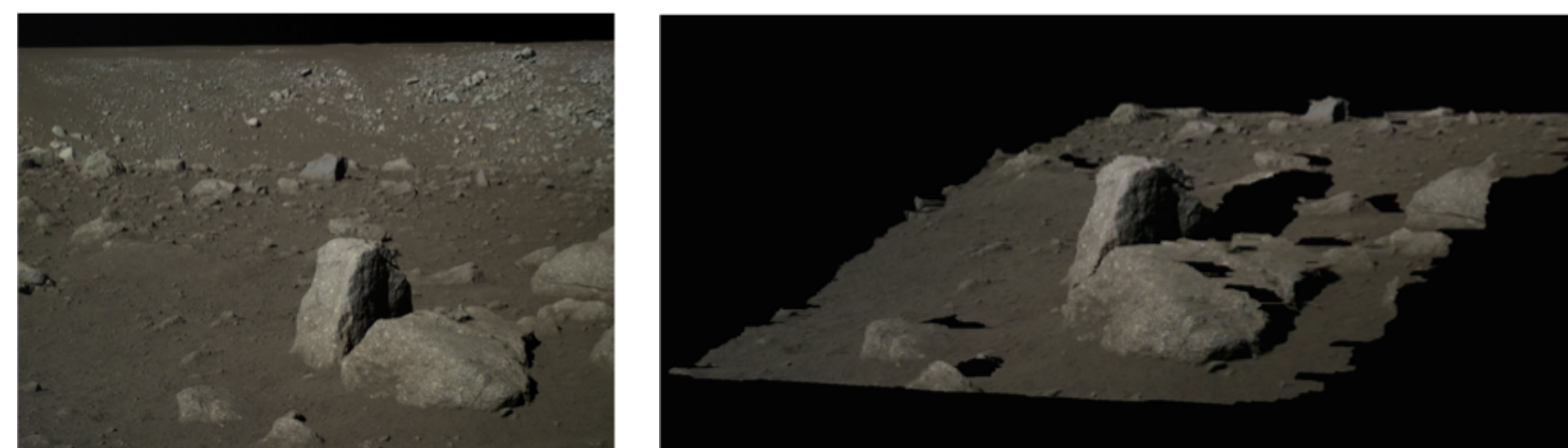
Space qualified sensors

- stereo navigation, hazard camera
- active lighting (flood and structured)
- IMU, lidar, sun trackers

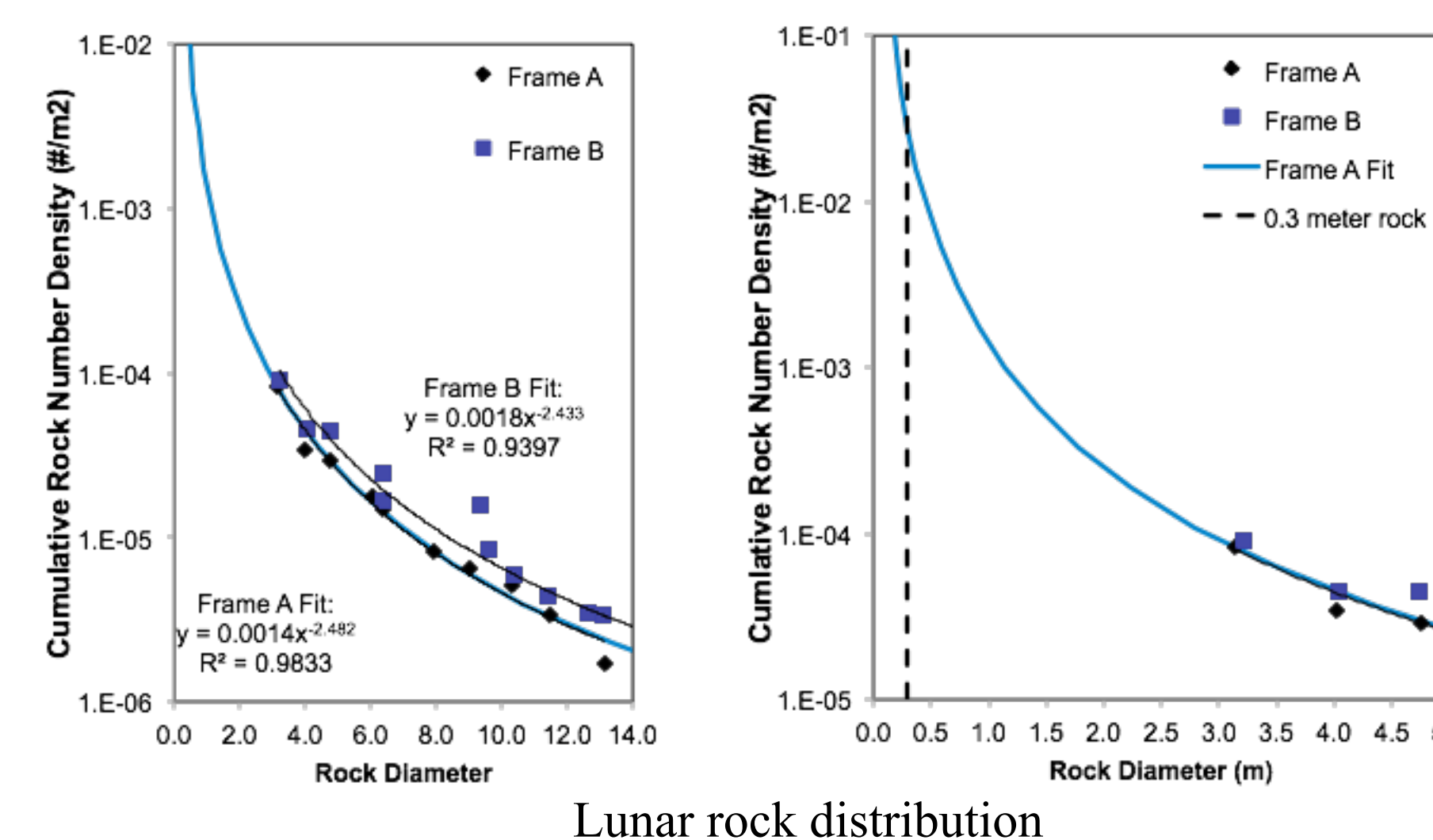
## Surface Characterization



Apollo 17 Lunar surface imagery

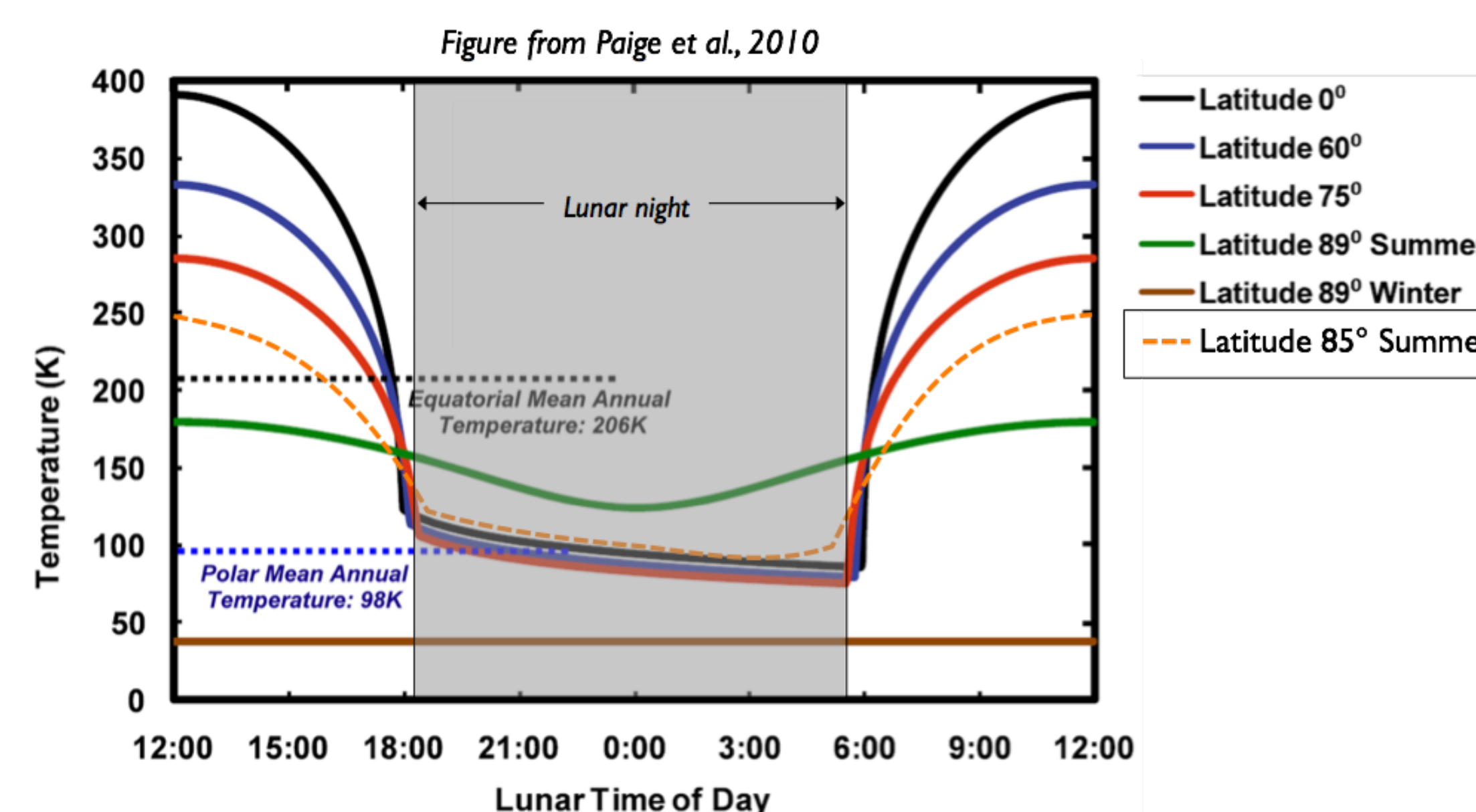


Cheng'e Lunar surface imagery (left) and reconstructed terrain (right).

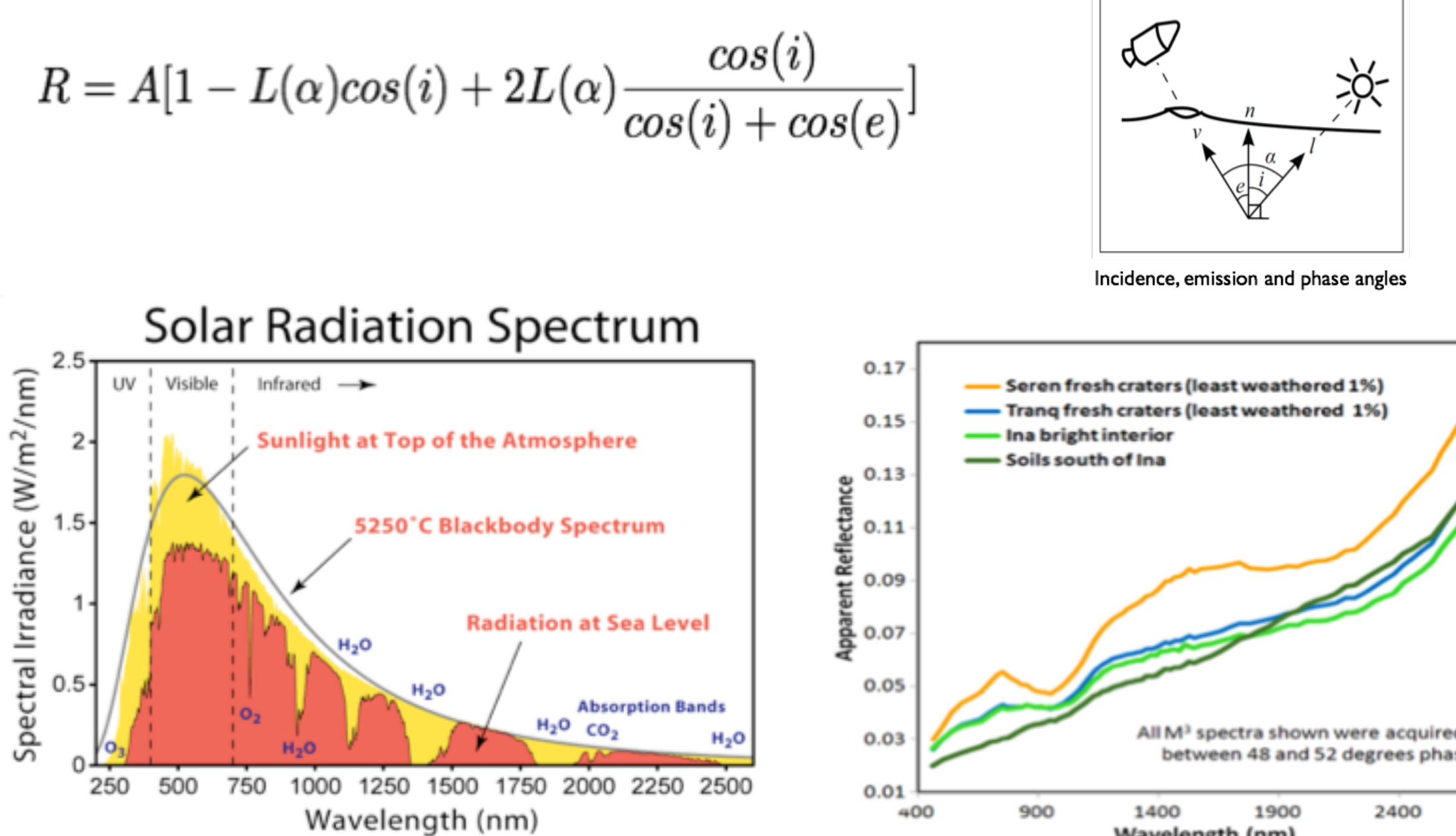


Lunar rock distribution

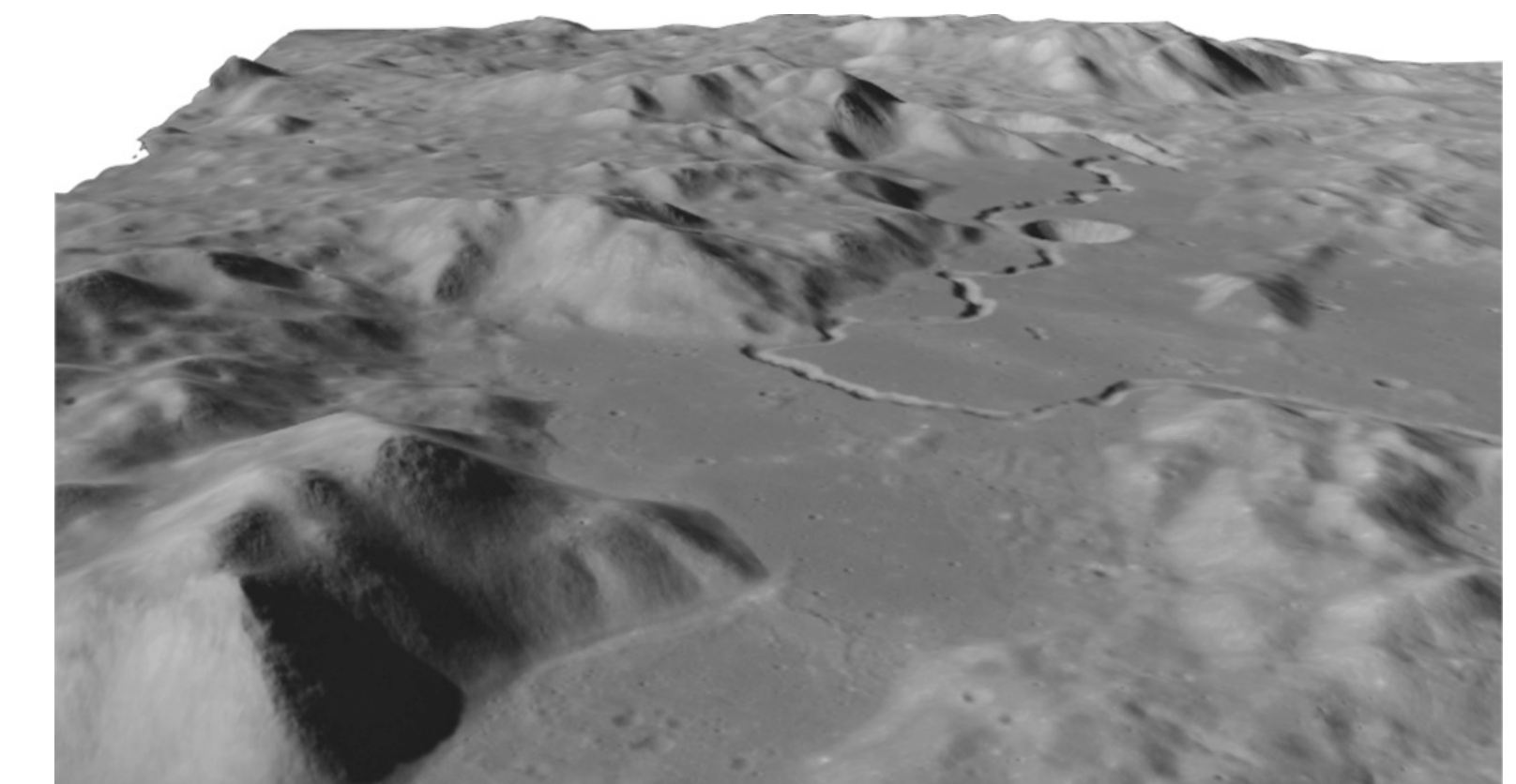
## Temperature Conditions



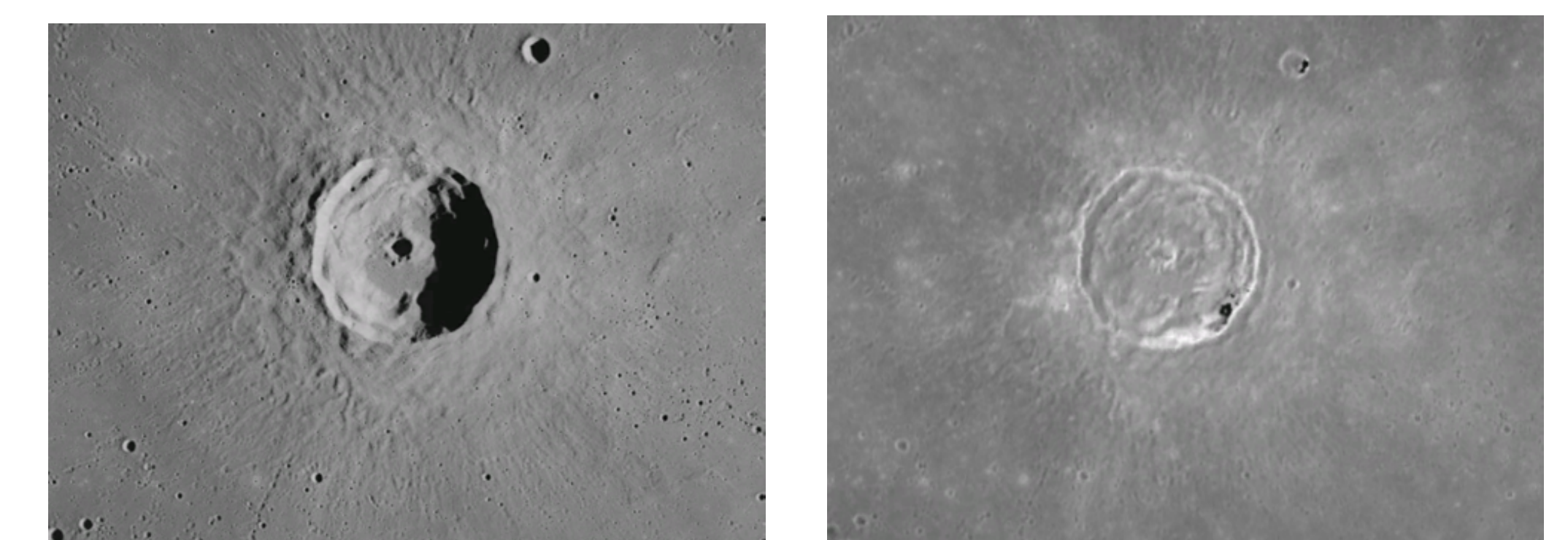
## Illumination Conditions



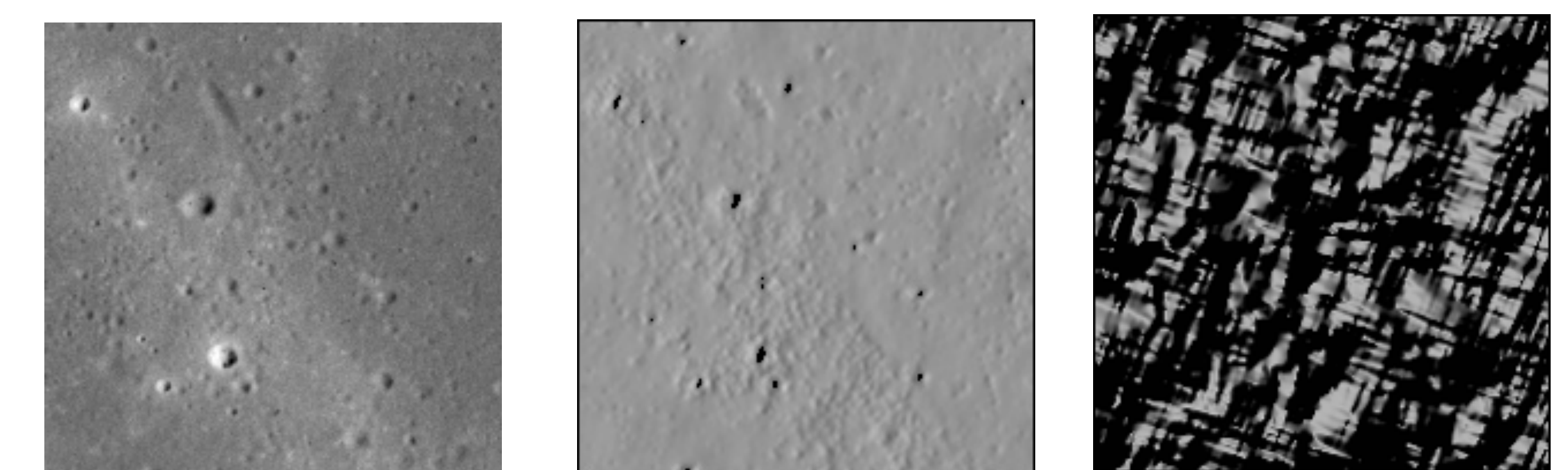
## Terrain Models From Orbital Data



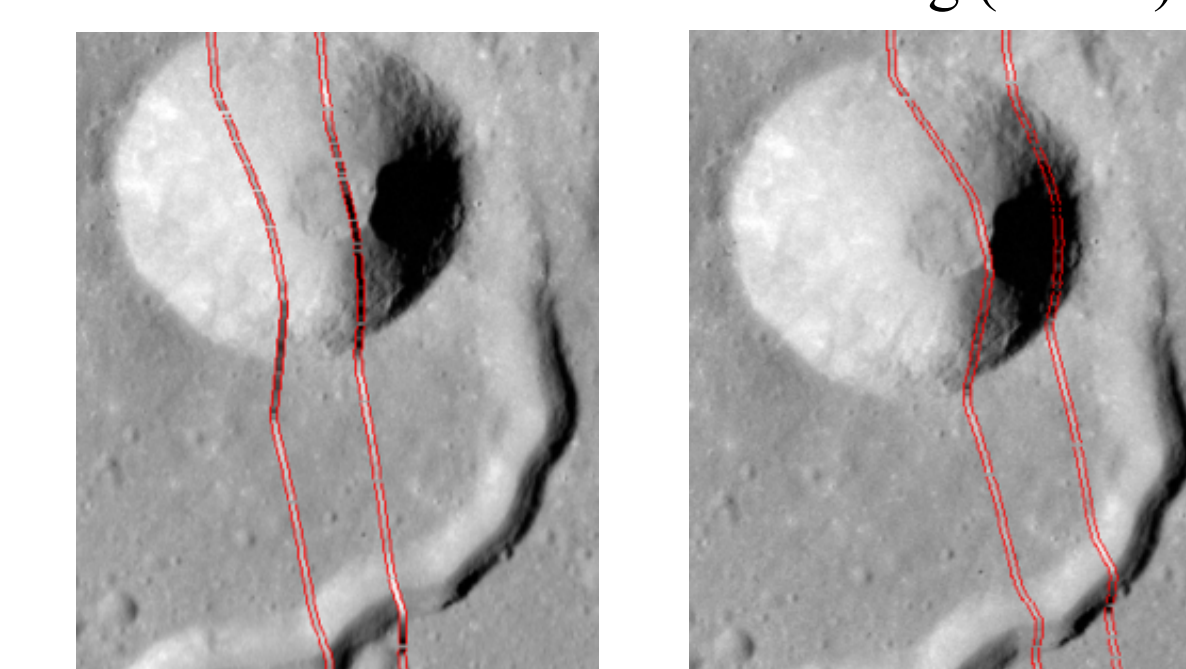
Stereo reconstruction: Oblique view of the Apollo 15 landing site (left) and crater detail (right).



Albedo Reconstruction: original image (left), reconstructed albedo (right)

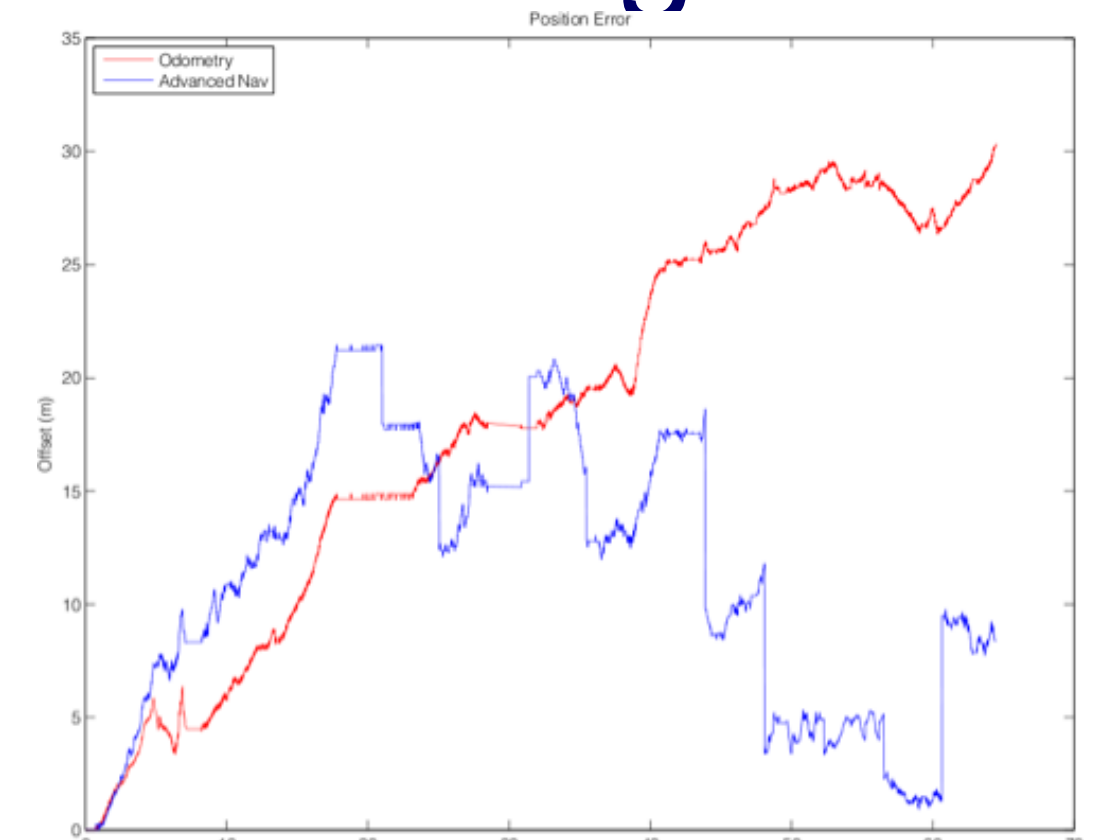


Shape from Shading: original image (left), hillshaded reconstructed terrain using shape from shading (center) and stereo (right)



Lidar to Image Co-registration: Original (left) LOLA tracks (red) and aligned tracks (right) over the orbital image

## On board / Off board Navigation



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